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(57) Abstract <p>The present invention relates to a bifunctional protein capable of directing a host cell producing said protein to specifically recognize selected target cells. Furthermore, the invention provides a method for the preparation of said protein, a DNA construct encoding said protein, a composition comprising a host cell expressing said DNA, and antibodies specifically recognizing said protein. Additionally, the invention relates to the use of such a host cell, e.g. for selectively killing tumor cells <i>in vitro</i> or <i>in vivo</i>.</p>		

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Bifunctional Protein, Preparation and Use

The present invention relates to a bifunctional protein capable of directing a host cell producing said protein to specifically recognize selected target cells. Furthermore, the invention provides a method for the preparation of said protein, a DNA construct encoding said protein, a composition comprising a host cell expressing said DNA, and antibodies specifically recognizing said protein. Additionally, the invention relates to the use of such a host cell, e.g. for selectively killing tumor cells in vitro or in vivo.

The principle of adoptive immunotherapy, also referred to as cellular immunotherapy, is the transfer of immunologically active cells to a mammal in order to enhance the mammal's immune response to a disease state. To this end the immune cells are removed e.g. from the human patient or another subject, cultured, optionally in the presence of immunoenhancing agents such as interleukin 2, and subsequently (re-)administered to the patient, conventionally in the presence of an immunoenhancing agent. In the patient, the immunologically active cells act to alleviate the disease state.

Immunologically active cells suggested for adoptive immunotherapy include lymphokine activated killer (LAK) cells, derived from natural killer (NK) cells, and in vitro sensitized lymphocytes (IVS), derived from cytolytic or cytotoxic T lymphocytes (CTL), also referred to as killer T lymphocytes. LAK cells are cytolytic cells which react with a broad spectrum of target cells. They are not major histocompatibility complex (MHC)-restricted and capable of lysing tumor cells, but also normal cells in vitro. CTL have clonal specificities, i.e. each clone is specific for a particular antigenic structure on the surface of a target cell. A particular CTL recognizes and binds a unique antigen and thus becomes activated and can then multiply and destroy the target cells. The recognition process is MHC-restricted and dependent, since an antigen is recognized only in association with one of the self class I MHC surface molecules expressed by the target cell.

Recognition of a specific antigen by T cells is mediated by the T-cell antigen receptor (TCR) (A. Weiss, Cell 73, 209-212 (1993)). Binding of a ligand to the receptor may trigger cellular effector programs, such as activation of tyrosine kinases, intracellular calcium ion release and interleukin 2 production (R.T. Abraham et al., Trends Biochem. Sci. 17, 434-438 (1992)).

The TCR is a multimeric surface complex comprising the products of at least six genes, all

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of which are required for efficient plasma membrane expression. The clonotypic alpha (α) and beta (β) chains of the TCR mediate specific target cell recognition. These chains are non-covalently associated with the non-polymorphic components of the CD3 complex gamma (γ), delta (δ), and epsilon (ϵ), and the zeta (ζ) chain. The disulfid-linked ζ homodimer is a transmembrane molecule and its cytoplasmic part plays a central role in the TCR-mediated signal transduction and induction of cytotoxicity. The ζ chain is capable of autonomous signal transduction, i.e. ζ alone is sufficient to mediate a response. Fusion of the ζ chain with an extracellular ligand binding domain may result in a molecule which can be activated by interaction with the ligand (S.J. Frank et al., *Science* 249, 174-177 (1990); C. Romeo & B. Seed, *Cell* 64, 1037-1046 (1990); F. Letourneur & R.D. Klausner, *Proc. Natl. Acad. Sci. USA* 88, 8905-8909 (1991)). An isoform of ζ , eta (η), represents an alternatively spliced form of the ζ gene transcript.

Tumor formation involves the mutation of oncogenes and tumor suppressor genes in somatic cells. Such mutations may result in structural alterations or in the overexpression of proteins. Both events might lead to alterations in the intracellular processing of these proteins and the presentation of new antigenic structures in association with the major histocompatibility antigens on the surface of the cells. The detection of antibodies directed against oncogene products in the serum of tumor patients is an indication that oncogene products can be antigenic. Further evidence for this antigenicity is the evocation of the cellular immune response. The occurrence of CTL which recognize and eliminate tumor cells has been demonstrated in a number of model systems (T. Boon, *Adv. Cancer Res.* 58, 177-210 (1992); M.W. Kast et al., *Cell* 59, 603-614 (1989); Disis et al., *Cancer Res.* 54, 16-20 (1994)).

Present strategies aimed at exploiting the cytolytic activity of T-lymphocytes, e.g. for the treatment of cancer, suffer from several shortcomings, such as MHC-restriction of the recognition process in naturally occurring CTL. There is a need for an approach to overcome the limitations currently encountered.

It is the object of the present invention to provide such an improved approach involving manipulation of CTL-recognition specificity, e.g. to make the altered CTL potent and selective anti-tumor agents. This approach is based on the identification of consistent genetic alterations in benign and particularly in malignant tumor cells. Providing CTL with a defined tumor cell specificity enables the targeting to defined tumor cells and MHC-unrestricted and MHC-independent destruction of said target cells. Tumor cell lysis

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by CTL grafted with a novel, MHC independent recognition specificity may be exploited in vitro (ex vivo) or in vivo, e.g. in a gene therapy approach involving cancer treatment.

The tumor cells are (pre-)defined or selected target cells in that they carry the antigenic structure (ligand) recognized and bound by the antigen binding domain which is part of the chimeric protein of the invention.

The present invention concerns a chimeric protein capable of directing a CTL to specifically recognize and kill selected tumor cells. More specifically, the present invention provides a chimeric protein comprising a recognition function, a hinge region and the ζ chain of the TCR, and a CTL producing one or more of such protein molecules. Binding of a cell-bound ligand to the recognition part of the chimeric protein of the invention leads to ζ chain-mediated signal transduction within the CTL and eventually results in the lysis of the cell carrying the ligand.

The chimeric protein of the invention is a protein which does not exist in nature. The protein is bifunctional in that it is capable of both specifically recognizing and binding to a particular antigenic structure (via its recognition function domain) and serving as a signalling component (via the ζ chain part). The hinge region serves as a spacer and ensures the necessary accessibility and flexibility of the recognition function domain. The hinge region is understood to be essential for the functionality of the chimeric protein of the invention. Preferably, the arrangement within the chimeric protein is such that the recognition function is located at the N-terminus and linked to the ζ chain part at the C-terminus of the chimeric protein via the hinge region. Being a cell surface receptor molecule the chimeric protein of the invention comprises an extracellular domain, a transmembrane domain and a cytoplasmic domain and is inserted into the plasma membrane of the host cell, e.g. the CTL. The functionality of the protein of the invention within the host cell is detectable in an assay suitable for demonstrating the signalling potential of said protein upon binding of a particular ligand, e.g. in an assay enabling detection of a signalling pathway triggered upon binding of the ligand, such as an assay involving measurement of the increase of calcium ion release, intracellular tyrosine phosphorylation, inositol phosphate turnover or interleukin (IL) 2, interferon γ , GM-CSF, IL-3, IL-4 production thus effected. (R.T. Abraham et al., *Trend Biochem. Sci.* 17, 434-438 (1992)). Such assays are readily available to the person with ordinary skill in the art. Reference is made to the assays employed in the Examples. It is evident that these assays may be modified, e.g. by using other suitable cell lines.

The recognition function is contributed by an antigen binding domain of an antibody, particularly a single chain antibody (scFv). Single chain antibodies are gene fusions comprising the variable domains of the heavy and light chain of monoclonal antibodies. Said recognition and binding function is conferred to the ζ -chain of the TCR-complex to circumvent MHC-restricted antigen recognition through the α/β chains of the TCR.

The antigen binding domain is derivable from a monoclonal antibody directed against and specific for a suitable antigen on a tumor cell.

A suitable antigen is an antigen with enhanced or specific expression on the surface of a tumor cell as compared to a normal cell, e.g. an antigen evolving from consistent genetic alterations in tumor cells. Examples of suitable antigens include ductal-epithelial mucine, gp 36, TAG-72, growth factor receptors and glycosphingolipids and other carbohydrate antigens preferentially expressed in tumor cells (Please give references for the below captioned antigens and antibodies). Ductal-epithelial mucine is enhancedly expressed on breast, ovarian and pancreas carcinoma cells and is recognized e.g. by monoclonal antibody SM3 (Zotter et al., Cancer Rev. 11, 55-101 (1988)). The glycoprotein gp 36 is found on the surface of human leukemia and lymphoma cells. An exemplary antibody recognizing said antigen is SN 10. TAG-72 is a pancarcinoma antigen recognized by monoclonal antibody CC49 (Longenecker, Sem. Cancer Biol. 2, 355-356). Growth factor receptors are e.g. the human epidermal growth factor (EGF) receptor (Khazaie et al., Cancer and Metastasis Rev. 12, 255-274 (1993)) and HER2, also referred to as erbB-2 or gp 185 (A. Ullrich and J. Schlessinger, Cell 61, 203-212 (1990)). The erbB-2 receptor is a transmembrane molecule which is overexpressed in a high percentage of human carcinomas (N.E. Hynes, Sem. in Cancer Biol. 4, 19-26 (1993)). Expression of erbB-2 in normal adult tissue is low. This difference in expression identifies the erbB-2 receptor as "tumor enhanced".

Preferably, the antigen binding domain is obtainable from a monoclonal antibody produced by using as immunogen viable human tumor cells presenting the antigen in its native form. In a preferred embodiment of the invention, the recognition part of the chimeric protein specifically binds to an antigenic determinant on the extracellular domain of a growth factor receptor, particularly HER 2. Monoclonal antibodies directed to the HER2 growth factor receptor are known and are described, for example, by S.J. Mc Kenzie et al., Oncogene 4, 543-548 (1990), R.M. Hudziak et al., Molecular and

Cellular Biology 9, 1165-1172 (1989), International Patent Application WO 89/06692 (Genentech) and Japanese Patent Application Kokai 02-150 293 (Ajinomoto KK). Monoclonal antibodies raised against viable human tumor cells presenting HER2 in its native form, such as SKBR3 cells, are described, for example, in European patent application EP-A-502 812 (Ciba-Geigy) which is enclosed herein by reference, and include antibodies FRP5, FSP16, FSP77 and FWP51. Hybridoma cell lines producing these antibodies have been deposited with the European Collection of Animal Cell Cultures (ECACC, PHLS Centre for Applied Microbiology & Research, Porton Down, Salisbury, UK) on November 21, 1990 under accession numbers 90112115, 90112116, 90112117 and 90112118, respectively.

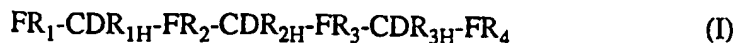
In the chimeric protein of the invention, the preferred antigen binding domain is a single-chain recombinant antibody (scFv) comprising the light chain variable domain (V_L) bridged to the heavy chain variable domain (V_H) via a flexible linker (spacer), preferably a peptide. Advantageously, the peptide consists of about 10 to about 30 amino acids, particularly naturally occurring amino acids, e.g. about 15 naturally occurring amino acids. Preferred is a peptide consisting of amino acids selected from L-glycine and L-serine, in particular the 15 amino acid peptide consisting of three repetitive units of Gly-Gly-Gly-Gly-Ser. Advantageous is a single-chain antibody wherein V_H is located at the N-terminus of the recombinant antibody. Preferred is a chimeric protein wherein the single-chain recombinant antibody has an above-defined preferred specificity, e.g. a chimeric protein comprising a single-chain recombinant antibody wherein the heavy chain variable domain and the light chain variable domain are derivable from a monoclonal antibody, e.g. a murine monoclonal antibody, directed to the human growth factor receptor HER2, such as a murine monoclonal antibody selected from the group consisting of FSP16, FSP77, FRP5 and FWP51.

The variable domain of an antibody heavy or light chain consists of so-called framework regions (FRs), which are fairly conserved in antibodies with different specificities, and of hypervariable regions also called complementarity determining regions (CDRs), which are typical for a particular specificity. In the antigen binding domain of a chimeric protein according to the invention, preferably the FRs are derivable from a mammalian, e.g. a murine or particularly a human antibody. The scFv derivative of a monoclonal antibody is grafted onto the ζ chain of the TCR/CD3 complex.

Particularly preferred is a chimeric protein comprising a single-chain recombinant

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antibody wherein the heavy chain variable domain comprises a polypeptide of the formula



wherein the polypeptide chain is described as starting at the N-terminal extremity and ending at the C-terminal extremity and FR_1 is a peptide residue comprising at least 25-29, preferably 25-33 naturally occurring amino acids, FR_2 is a peptide residue comprising 12-16 naturally occurring amino acids, FR_3 is a peptide residue comprising 30-34 naturally occurring amino acids, FR_4 is a peptide residue comprising at least 6-10, preferably 6-13 naturally occurring amino acids, $\text{CDR}_{1\text{H}}$ is a peptide residue of the amino acid sequence 31 to 35 of SEQ ID NO:2, $\text{CDR}_{2\text{H}}$ is a peptide residue of the amino acid sequence 50 to 66 of SEQ ID NO:2, and $\text{CDR}_{3\text{H}}$ is a peptide residue of the amino acid sequence 99 to 108 of SEQ ID NO:2, or, $\text{CDR}_{1\text{H}}$ is a peptide residue of the amino acid sequence 31 to 35 of SEQ ID NO:4, $\text{CDR}_{2\text{H}}$ is a peptide residue of the amino acid sequence 50 to 66 of SEQ ID NO:4, and $\text{CDR}_{3\text{H}}$ is a peptide residue of the amino acid sequence 99 to 109 of SEQ ID NO:4, and wherein the amino acid Cys may be in the oxidized state forming S-S-bridges. These particular complementarity determining regions are Asn-Tyr-Gly-Met-Asn ($\text{CDR}_{1\text{H}}$), Trp-Ile-Asn-Thr-Ser-Thr-Gly-Glu-Ser-Thr-Phe-Ala-Asp-Asp-Phe-Lys-Gly ($\text{CDR}_{2\text{H}}$), and Trp-Glu-Val-Tyr-His-Gly-Tyr-Val-Pro-Tyr ($\text{CDR}_{3\text{H}}$) according to SEQ ID NO:2, or Ser-Tyr-Trp-Met-Asn ($\text{CDR}_{1\text{H}}$), Met-Ile-Asp-Pro-Ser-Asp-Ser-Glu-Thr-Gln-Tyr-Asn-Gln-Met-Phe-Lys-Asp ($\text{CDR}_{2\text{H}}$) and Gly-Gly-Ala-Ser-Gly-Asp-Trp-Tyr-Phe-Asp-Val ($\text{CDR}_{3\text{H}}$) according to SEQ. ID NO:4.

Especially preferred is a chimeric protein wherein the recombinant single-chain antibody comprises a heavy chain variable domain of formula I, wherein the framework regions FR_1 , FR_2 , FR_3 and FR_4 are those preferably derivable from a mammalian, especially a murine or a human antibody.

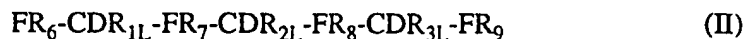
In a first embodiment of the invention, most preferred is a chimeric protein wherein the heavy chain variable domain of the recombinant single-chain antibody comprises a polypeptide of the amino acid sequence 2 to 120, of SEQ ID NO:2, wherein optionally one or more, e.g. 1, 2, 3 or 4, single amino acids within the amino acid sequences 2 to 30 (FR_1), 36 to 49 (FR_2), 67 to 98 (FR_3), and/or 110 to 120 (FR_4), are replaced by other amino acids or deleted, and wherein the amino acid Cys may be in the oxidized state forming S-S-bridges, in particular a chimeric protein wherein the heavy chain variable domain comprises a polypeptide of the amino acid sequence 6 to 119 of SEQ ID NO:2,

wherein the amino acid Cys may be in the oxidized state forming S-S-bridges.

In a second embodiment of the invention, most preferred is a chimeric protein wherein the heavy chain variable domain of the recombinant single-chain antibody comprises a polypeptide of the amino acid sequence 2 to 120 of SEQ ID NO:4, wherein optionally one or more, e.g. 1, 2, 3 or 4, amino acids within the amino acid sequences 2 to 30 (FR₁), 36 to 49 (FR₂), 67 to 98 (FR₃), and/or 110 to 120 (FR₄), are replaced with other amino acids or deleted, and wherein the amino acid Cys may be in the oxidized state forming S-S-bridges, in particular the recombinant antibodies with a heavy chain variable domain comprising a polypeptide of the amino acid sequence 6 to 120 of SEQ ID NO:4, wherein the amino acid Cys may be in the oxidized state forming S-S-bridges.

For example, a hydrophobic amino acid within a framework region may be replaced by another amino acid, preferably also a hydrophobic amino acid, e.g. a homologous amino acid, replaced with two amino acids (resulting in the insertion of an amino acid), or deleted. Likewise, a hydrophilic amino acid within a framework region may be replaced with another amino acid, two amino acids or deleted, whereby replacing amino acids preferably maintain the hydrogen bond structure of the corresponding framework region. Advantageously, any replacement of one or more amino acids takes into account the guidelines known in the art for reshaping or humanizing of an antibody. Particularly noteworthy are guidelines aimed at reducing the immunogenicity of the reshaped antibody (as compared to the "original" monoclonal antibody) and/or at designing an antibody which about equals or exceeds the binding affinity of the "original" antibody. A modification of amino acids may be confined to a single FR, i.e. FR₁, FR₂, FR₃ or FR₄, or involve two, three or all four of the FRs.

A likewise preferred chimeric protein of the invention comprises a recombinant single-chain antibody wherein the light chain variable domain comprises a polypeptide of the formula



wherein the polypeptide chain is described as starting at the N-terminal extremity and ending at the C-terminal extremity and FR₆ is a peptide residue comprising naturally occurring amino acids, preferably 19-25, especially 19-23 naturally occurring amino acids, FR₇ is a peptide residue comprising 13-17 naturally occurring amino acids, FR₈ is a

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peptide residue comprising 30-34 naturally occurring amino acids, FR₉ is a peptide residue comprising naturally occurring amino acids, particularly 7-11 naturally occurring amino acids, and CDR_{1L} is a peptide residue of the amino acid sequence 158 to 168 of SEQ ID NO:2, CDR_{2L} is a peptide residue of the amino acid sequence 184 to 190 of SEQ ID NO:2, and CDR_{3L} is a peptide residue of the amino acid sequence 223 to 231 of SEQ ID NO:2, or CDR_{1L} is a peptide residue of the amino acid sequence 159 to 164 of SEQ ID NO:4, CDR_{2L} is a peptide residue of the amino acid sequence 185 to 191 of SEQ ID NO:4, and CDR_{3L} is a peptide residue of the amino acid sequence 224 to 231 of SEQ ID NO:4, and wherein the amino acid Cys may be in the oxidized state forming S-S-bridges. These particular complementarity determining regions are Lys-Ala-Ser-Gln-Asp-Val-Tyr-Asn-Ala-Val-Ala (CDR_{1L}), Ser-Ala-Ser-Ser-Arg-Tyr-Thr (CDR_{2L}), and Gln-Gln-His-Phe-Arg-Thr-Pro-Phe-Thr (CDR_{3L}) according to SEQ ID NO:2, or Lys-Ala-Ser-Gln-Asp-Ile-Lys-Lys-Tyr-Ile-Ala (CDR_{1L}), Tyr-Thr-Ser-Val-Leu-Gln-Pro (CDR_{2L}) and Leu-His-Tyr-Asp-Tyr-Leu-Tyr-Thr (CDR_{3L}) according to SEQ ID NO:4.

Especially preferred is a chimeric protein wherein the recombinant antibody comprises a light chain variable domain of formula II, wherein the peptide residues of the framework regions FR₅, FR₆, FR₇ and FR₈ are those derivable from a mammalian, especially a murine or a human, antibody.

In one embodiment of the invention, most preferred is a chimeric protein wherein the recombinant antibody comprises a light chain variable domain comprising a polypeptide of the amino acid sequence 135 to 240 of SEQ ID NO:2, wherein optionally one or more, e.g. 1, 2, 3 or 4, amino acids within the amino acid sequences 135 to 157 (FR₆), 169 to 183 (FR₇), 191 to 222 (FR₈), and/or 232 to 240 (FR₉) are replaced by other amino acids or deleted, and wherein the amino acid Cys may be in the oxidized state forming S-S-bridges, in particular a light chain variable domain comprising a polypeptide of the amino acid sequence 135 to 240 of SEQ ID NO:2, wherein the amino acid Cys may be in the oxidized state forming S-S-bridges.

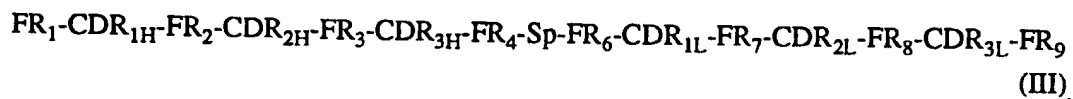
In a second embodiment of the invention, most preferred is a chimeric protein wherein the recombinant antibody comprises a light chain variable domain comprising a polypeptide of the amino acid sequence 136 to 240 of SEQ ID NO:4, wherein optionally one or more, e.g. 1, 2, 3 or 4 single amino acids within the amino acid sequences 136 to 158 (FR₆), 170 to 184 (FR₇), 192 to 223 (FR₈), and/or 232 to 240 (FR₉) are replaced by other amino acids or deleted, and wherein the amino acid Cys may be in the oxidized state forming

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S-S-bridges, in particular a light chain variable domain comprising a polypeptide of the amino acid sequence 136 to 240 of SEQ ID NO:4, wherein the amino acid Cys may be in the oxidized state forming S-S-bridges.

For example, amino acids within the framework regions may be replaced by other amino acids or deleted as detailed above for the heavy chain.

Especially preferred is a chimeric protein comprising a single-chain recombinant antibody wherein the heavy chain variable domain and the light chain variable domain are linked by way of a spacer group consisting of 10 to 30, e.g. about 15, amino acids, in particular a single-chain recombinant antibody comprising a polypeptide of the formula



wherein the polypeptide chain is described as starting at the N-terminal extremity and ending at the C-terminal extremity and FR₁, CDR_{1H}, FR₂, CDR_{2H}, FR₃, CDR_{3H}, FR₄, FR₆, CDR_{1L}, FR₇, CDR_{2L}, FR₈, CDR_{3L} and FR₉ have the meanings as mentioned before and Sp is a peptide spacer as disclosed above.

The antigen binding domain may be tested for its specificity to a predefined tumor cell antigen by methods known in the art, for example by immunofluorescent staining of cells expressing high levels of the antigen, by immunoblotting either directly or by way of immunoprecipitation and protein blotting of the immunocomplexes, or by another immunoassay such as binding, crossinhibition or competition radio- or enzyme immunoassay. The binding affinity of the antigen binding domain may be determined using a suitable quantitative assay which can easily be established by a person with ordinary skill in the art based on known techniques and principles. If desired, the affinity of the antigen binding domain may be compared to the affinity of a suitable reference antibody, e.g. the "parental" monoclonal mouse antibody it is derivable from.

Additionally to the antigen binding domain the chimeric protein of the invention comprises a hinge region which is inserted as a short, flexible tether between the antigen binding domain and the ζ domain. The hinge region is a peptide comprising from about 40 to about 200 naturally occurring amino acids, preferably from about 60 to about 190 amino acids. Preferably, the hinge region in the chimeric protein according to the

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invention is an immunoglobulin-like hinge region, e.g. a hinge region derivable from the CD4 molecule, such as the D3D4 immunoglobulin domains (P.J. Maddon et al., Proc. Natl. Acad. Sci. USA. 84, 9155-9159 (1987)) or a hinge region derivable from the CD8 α molecule, e.g. Lyt-2 (R. Zomowska et al., Cell 43, 153-163 (1985); B.J. Classon et al., Int. Immunol. 4, 2, 215-225 (1992)). In the amino acid sequence set forth in SEQ ID No. 7 the hinge region (Lyt-2) extends from the amino acid at position 245 to the amino acid at position 304.

Additionally to the antigen binding domain and the hinge region the chimeric protein of the invention comprises a functional ζ domain contributing the transmembrane and the signalling domain of the chimeric protein. A functional ζ domain essentially comprises the transmembrane and the cytoplasmic domain of the ζ chain. The ζ domain mediated activation of the TCR by interaction of the antigen binding domain of the chimeric protein of the invention with a specific antigen triggers several signalling pathways, e.g. the ones mentioned above. According to the invention the ζ chain is of mammalian, particularly murine or human origin. Within the TCR ζ exists as a $\zeta\zeta$ disulphide homodimer. A functional ζ domain is a protein which upon expression in T cell hybridomas deficient in endogenous ζ expression is capable of restoring in said hybridomas a functionally active TCR, e.g. in such a way that antigen-induced interleukin-2 secretion and growth stimulation are regained (S. Frank et al., Science 249, 174-177 (1990)). Examples of a functional ζ domain include molecules comprising amino acids 28 to 164 of the murine (A.M. Weissman, Science 239, 1018-1021 (1988)) and amino acids 28 to 163 of the human ζ chain (numbering according to A.M. Weissmann et al., Proc. Natl. Acad. Sci. USA 85, 9709-9713 (1988), Fig. 2, which is incorporated herein by reference). It is envisaged that a ζ protein as used for the purpose of the present invention is intended to include variants with the provision that these variants are functional. Preferred are variants of mammalian, particularly murine and human origin.

For example, a variant is a naturally occurring variant of the ζ molecule as found within a particular species. Such a variant may be encoded by a related gene of the same gene family or an allelic variant of a particular gene. The term "variant" also embraces a modified ζ molecule producible from a DNA which has been subjected to in vitro mutagenesis, with the provision that the protein encoded by the DNA has the functional activity of the authentic ζ molecule. Such modifications may consist in an addition, exchange and/or deletion of one or more amino acids, the latter resulting in shortened variants.

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A preferred chimeric protein of the invention comprises a protein having the amino acid sequence depicted in SEQ ID No. 7.

Moreover, the invention relates to a polyclonal and monoclonal antibody specifically binding to a protein of the invention. Such an antibody is prepared according to conventional methods well known in the art.

The chimeric protein of the invention may be prepared by a process that is known per se, characterized in that suitable host cells as defined further below producing a protein of the invention, are multiplied in vitro or in vivo, and, if desired, the protein is isolated. Preferably, a protein of the invention is produced by a process comprising culturing suitable transduced CTL under conditions which allow the expression of the DNA construct encoding the protein and, optionally, performing an assay detecting the functionality of the protein. The invention further concerns a method for the manufacture of a chimeric protein of the invention comprising culturing a suitable host cell, particularly a CTL, which has been transduced with a vector comprising an expression cassette comprising a promoter and a DNA coding for said protein which DNA is controlled by said promoter under conditions which allow the expression of said DNA. A preferred chimeric protein of the invention is constructed to include a scFv, a hinge region and a functional ζ molecule. The process for producing the chimeric protein of the invention should yield the protein in an amount sufficient to enable the transduced host cell to lyse a target cell.

Suitable host cells include e.g. primary cytotoxic T lymphocytes (CD 8⁺), CD 4⁺ T helper cells and natural killer cells (NK). Preferred are mammalian cells, especially CTL of mammalian, particularly human origin.

As used hereinbefore or hereinafter, in vitro means ex vivo, thus including cell culture conditions.

For example, multiplication of mammalian cells in vitro is carried out in suitable culture media, which are customary standard culture media, such as Dulbecco's Modified Eagle Medium (DMEM) or RPMI 1640 medium, optionally replenished by a mammalian serum, e.g. fetal calf serum, or trace elements and growth sustaining supplements, e.g. feeder cells.

The invention also concerns a recombinant DNA or DNA construct suitable for manipulating the recognition specificity of T-lymphocytes. More specifically, the present invention provides a DNA construct capable of directing the synthesis of a chimeric protein comprising a recognition function, a hinge region and the ζ -chain as a signalling component of the TCR. In particular, the invention provides a DNA construct encoding a chimeric protein comprising an antigen binding domain, a hinge region and a ζ domain, particularly a DNA construct comprising at least one polynucleotide coding for a protein part designated as preferred hereinbefore or hereinbelow. In a preferred arrangement the antigen binding domain is conceived as the first part, the hinge region as the second part and the ζ chain as the third part.

By definition the DNAs of the invention include coding single stranded DNAs, double stranded DNAs consisting of said coding DNAs and DNA complementary thereto, or these complementary (single stranded) DNAs themselves.

Advantageously, the DNA construct of the invention comprises a fourth part which is located upstream of the first part (the antigen binding domain) and which encodes a leader peptide. Preferably, the fourth part of the DNA construct of the invention encodes a leader peptide of an immunoglobulin (Ig) gene, e.g. an Ig heavy chain leader peptide. The Ig heavy chain leader peptide promotes targeting of nascent polypeptides to the lumen of the endoplasmic reticulum; it is subsequently cleaved off and the protein is sorted through the Golgi and the membrane to its transmembrane location. Particularly preferred is a leader peptide having the sequence: Met-Ala-Trp-Val-Trp-Thr-Leu-Leu-Phe-Leu-Met-Ala-Ala-Ala-Lys-Val-Pro-Lys.

Preferred is a DNA comprising a DNA encoding the protein with the amino acid sequence depicted in SEQ ID No.7, e.g. a DNA having the nucleotide sequence depicted in SEQ ID No. 5. The DNA sequence set forth in SEQ ID No. 7 has the following features:
description of the sequence: 5'-EcoRI-IgH chain leader D6/12-scFv(FRP5):Lyt-2 hinge:-CD3 zeta(transmembrane (TM) and cytoplasmic (Cyt))-EcoRI-3'

5'EcoRI site:	position 1
3'RcoRI site:	position 1474
ATG initiation	position 40
TAA stop	position 1423
IGH chain leader	position 40-93

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scFv(FRP5)	position 94-819
lyt-2 hinge insert	XbaI (position 819)-
	XbaI (position 1005)
zeta insert	XbaI (position 1005)-
	EcoRI (position 1474)

The present state of the art is such that a person with ordinary skill in the art will be able to synthesize a DNA molecule of the invention given the written information provided herein. A suitable method for obtaining a DNA construct of the invention involves methods well-known in the art comprising e.g. synthesis of a number of oligonucleotides, amplification of specific gene sequences, e.g. using PCR (polymerase chain reaction) technology, their splicing to give the desired DNA sequence and/or use of DNA restriction enzymes and ligases. A DNA of the invention may be synthesized by combining chemical with recombinant methods.

The invention further concerns a vector, such as a retroviral vector, comprising a DNA construct of the invention.

Additionally, the present invention provides a genetically engineered transduced CTL which is capable of destroying a targeted tumor cell in an MHC-independent and MHC-unrestricted manner. According to the present invention, the CTL produces the above-identified chimeric protein of the invention. The CTL is transduced with a DNA of the invention and thus is capable of expressing said DNA and of producing the protein encoded by said DNA. Destruction of the targeted tumor cell requires that the protein thus produced is functional, i.e. the antigen binding domain of said protein must be capable of recognizing and binding to the targeted tumor cell and the ζ domain must be capable of triggering the desired signal within the CTL. The CTL of the invention is cultured under conditions enabling (favoring) the expression of the introduced DNA and, if desired, assayed for the production thereof. Prolonged and elevated expression of said DNA is preferred.

Furthermore, the present invention provides a process for endowing a CTL with a defined, MHC-independent and MHC-unrestricted tumor cell specificity by introducing into said T-lymphocyte a DNA construct comprising a recognition function, a spacer domain and the ζ -chain as a signalling component of the TCR. The DNA construct may be introduced into the CTL by DNA-transfer methods apparent to those skilled in the art, e.g. by means

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of a vector system, such as a viral or non-viral vector system. Suitable viral vectors include retroviral, adenoviral and adeno-associated viral vectors. The process is applicable to both in vivo and in vitro situations. In vitro application is preferred.

The T-lymphocyte is cultured under conventional conditions allowing the expression of said DNA construct and assayed for the production thereof. Prolonged and elevated expression of said DNA is preferred. Advantageously, CTL are cultured in the presence of IL-2. Transduced CTL of the invention may be selected for a suitable marker. For example, the transduced CTL may be selected for the cotransduced neo resistance marker if the DNA construct of the invention is transferred via a retroviral vector.

Moreover, the invention relates to a composition of matter comprising the transduced CTL of the invention. Such a composition comprises e.g. transduced CTL producing a protein of the invention together or in admixture with an acceptable, e.g. a pharmaceutically acceptable, carrier. Such a carrier may be a solid or liquid carrier. The composition may be used ex vivo, e.g. in order to kill preselected target cells in a composition (for example body liquid or tissue) removed from a patient's body. After the target cells have been killed (which should be checked) the composition is re-introduced into the patient's body. Thus the composition of the invention may be used for the treatment or adjuvant treatment of tumors.

Additionally, the present invention provides a process for lysing selected tumor cells comprising contacting said tumor cells to CTL producing the chimeric protein of the invention. In the process which is applicable to both in vitro and in vivo situations the tumor cell is targeted by the antigen binding domain which is part of the chimeric protein of the invention.

It is preferred to use the host's own CTL, particularly if the exposure and interaction is to occur in vivo, but, if appropriate, the CTL may also be derived from other sources. Other sources are e.g. tissue culture or another mammal of the same or different species.

CTL are found throughout the body of the mammal: in tissues, the lymphatic system and in the blood. Suitable CTL are selected and removed from the mammal. For example, CTL are selected as CD8⁺ peripheral lymphocytes cultured in vitro in the presence of IL-2. Alternatively, unselected peripheral lymphocytes are used for gene transduction. If desired, the host may be treated such as to increase the number of stimulated CTL.

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The invention further concerns a method of treating cancer comprising the use of the genetically engineered CTL of the invention. The method comprises exposing selected tumor cells to CTL producing the chimeric protein of the invention. An in vitro (meaning ex vivo) application of this method for promotion of CTL-mediated lysis may be in the selective treatment of tumor cells removed from a mammal, particularly a human, in the need of cancer treatment. An example would be to use the CTL of the invention to eliminate tumor cells from bone marrow removed from a patient, e.g. a patient undergoing radiation treatment prior, to re-introducing the bone marrow. As a consequence of the interaction of the tumor cells and the CTL of the invention the tumor cells are lysed. If the method of treating cancer is performed in vivo it may further comprise re-introducing the transduced CTL of the invention into the body of the mammal, particularly the human, to be treated. It is also envisaged that CTL expressing a DNA of the invention are produced by in vivo transduction of the DNA, e.g. in a mammal in need of cancer treatment.

The invention further concerns the CTL of the invention or a composition comprising said CTL for use in a method of treating cancer.

The invention particularly concerns the specific embodiments (e.g. protein, DNA, CTL and methods for the preparation thereof) described in the Examples. The following examples illustrate the invention but do not limit it to any extent.

Abbreviations: FCS: fetal calf serum; LDH: lactate dehydrogenase; mAb: monoclonal antibody; MoMLV: Moloney murine leukemia virus; MoMLV-LTR: Moloney murine leukemia virus-long terminal repeat, scFv: single chain antibody; SDS-PAGE: sodium dodecylsulfate polyacrylamide gel electrophoresis.

Materials and Methods

Cell Lines and Culture Conditions

Clone 96 (CI96) is a H-2K^d-restricted cytotoxic T cell line derived from C57BL/6 mice (K. Eichmann et al., J. Immunol. 147, 2075-2081 (1991)). CI96 and infectants are maintained in Dulbecco's modified Eagle's medium (DMEM, Gibco) supplemented with 10% FCS (Boehringer), 5×10^{-5} M 2-mercaptoethanol, 10 mM HEPES, 2 mM L-glutamine and 3% conditioned supernatant obtained from X63Ag8-653 plasmacytoma cells transfected with the murine IL-2 cDNA (H. Karasuyama and F. Melchers, Eur. J. Immunol. 18, 97-104 (1988)). The human leukemic T cell line Jurkat, the retroviral

packaging cell lines Ω E (J.P. Morgenstern and H. Land, Nuc. Acids Res. 18, 3587-3596 (1990)) and P317 (A.D. Miller and G.J. Rosman, Biotechniques 7, 980-990 (1989)) and infectants and the murine fibroblast cell line transfected with the activated human erbB-2 receptor, NIH3T3#3.7 are cultured in DMEM supplemented with 10% FCS. HC11R1#11 is a mouse mammary epithelial cell line transfected with the human erbB-2 proto-oncogene (N.E. Hynes et al., Mol. Cell. Biol. 10, 4027-4034 (1990)) which is grown in RPMI 1640 (Gibco) supplemented with 10% FCS, 10 ng/ml epidermal growth factor and 5 μ g/ml insulin.

Example 1: Construction of the scFv(FRP5):hinge:zeta(ζ) cDNA

A DNA consisting of a recognition function, a spacer domain and the ζ -chain as a signalling component of the TCR/CD3 receptor complex is constructed. The recognition function is contributed by a scFv domain. This domain is derived from the monoclonal antibody FRP5 (European patent application EP-A-502 812). FRP5 is specific for the extracellular domain of the erbB-2 receptor. The scFv (FRP5) comprises the variable domains of the heavy and light chains (V_H and V_L) of the monoclonal antibody (mAb) joined by a 15 amino acid linker sequence (SEQ ID NO:2). This scFv domain is able to recognize the extracellular domain of the erbB-2 receptor (W. Wels et al., Biotechnology 10, 1128-1132 (1992); W. Wels et al., Cancer Res. 15, 6310-6317 (1992)). A leader sequence from an immunoglobulin heavy chain is added to the N-terminus of the scFv domain. The scFv(FRP5) cDNA is ligated to a short linker sequence encoding 59 amino acids from the immunoglobulin-like hinge region of the CD8 α gene (R. Zomoyka et al., Cell 43, 153-163 (1985)). The transmembrane and signalling domain are contributed by the ζ -chain of the TCR. This chain is responsible for the signal transduction following TCR activation.

The cDNA encoding the single chain antibody FRP5 specific for the extracellular domain of the erbB-2 molecule (SEQ ID NO:1) is subcloned into a plasmid containing an immunoglobulin heavy chain leader (L_{IgH}). Both, the ζ cDNA and the CD8 α hinge cDNA are derived from total RNA of the cytotoxic T cell line CI96 using a combination of reverse transcription and the polymerase chain reaction (RT-PCR). MoMLV reverse transcriptase is used for first strand cDNA synthesis. The reactions are primed with the 3' ζ -specific oligonucleotide 5813 (SEQ ID NO:6) or the 3' CD8 α -specific oligonucleotide 8764 (SEQ ID NO:7), respectively. These cDNAs are used as PCR templates with the ζ primer pair 5812/5813 (SEQ ID NOs. 8 and 6) introducing a 5' XbaI site and a 3' HindIII/BglII site and the CD8 α hinge primer pair 8763/8764 (SEQ ID NOs. 10 and 8)

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introducing a XbaI site at both ends. The L_{IgH}-scFv(FRP5) DNA is ligated to the ζ cDNA starting from amino acid residue 28 (numbering according to A.M. Weissman et al., Science 239, 1018-1021 (1988)) using the XbaI site for the fusion. The CD8 α hinge cDNA encoding amino acid residues 105 to 164 (numbering according to R. Zomoyka et al., Cell 43, 153-163 (1985)) is subsequently inserted into the XbaI site and checked for right orientation. The resulting scFv:hinge: ζ cDNA construct (SEQ ID No. 7) is confirmed by complete DNA sequencing and eventually subcloned into the unique EcoRI site of the pLXSN retroviral vector (A.D. Miller and G.J. Rosman, supra) resulting in the pL(scFv(FRP5):hinge: ζ)SN construct. The expression of the DNA is controlled by the 5' MoMLV-LTR. The plasmid also bears a selectable marker for neomycin resistance driven by the SV40 early promoter (SN).

Cloning of pL(scFv:D3/D4: ζ)SN

While the first molecular design includes the relatively short and flexible immunoglobulin hinge-like region of the murine Lyt-2 or CD8 α molecule as tether, the second design encompasses the two membrane-proximal immunoglobulin-like domains designated as D3 and D4 of the murine L3T4 or CD4 molecule (S.J. Clark et al., Proc. Natl. Acad. Sci. USA 84, 1649-1653 (1987)) as a longer and more rigid spacer. D3/D4 encoding cDNA is obtained by PCR using pcd-L3T4 4.25 plasmid DNA (D.R. Littman and S.N. Gettner, Nature 325, 453-455 (1987)). The specific primer pair #8761/#8762 amplifies the coding sequences for amino acid residues 184-370 of the CD4 molecule (P.J. Maddon et al., Proc. Natl. Acad. Sci. USA 84, 9155-9159 (1987)) introducing XbaI restriction sites at both ends of the cDNA. The product is subcloned into the XbaI site of the pL(FZ)SN vector. After checking for the correct orientation of the insert, sequence identity of the resulting construct is confirmed by DNA sequencing. The structure of the pL(F4Z)SN is shown in Figure 1.

Primers for the amplification of the L3T4/CD4D3/D4 cDNA:

'Upstream' -5' Lyt-2/CD8-specific oligonucleotide #8761¹⁾:

#8761: 5'-AGCTTCTAGAGTTTCAGAGCACAGCTCTCACGGCC-3'

'Downstream' -3' Lyt-2/CD8-specific oligonucleotide #8762¹⁾:

#8762: 5'-TCGATCTAGAGTCTGGTTCACCCCTCTGG-3'

¹⁾ XbaI restriction sites are underlined.

Example 2: Expression of the scFv(FRP5):hinge:ζ DNA after retroviral gene transfer

The pLXSN vector system is capable of directing the efficient synthesis of the scFv(FRP5):hinge:ζ DNA after transduction into cytotoxic T cells and allows for G418 selection of infected cells. An established murine CTL line, C196, is infected with the pL(scFv(FRP5):hinge:ζ)SN construct of Example 1.

The ecotropic packaging cell line ΩE is transfected by calcium-phosphate precipitation with pL(scFv(FRP5):hinge:ζ)SN plasmid DNA. Transfected cells are stably selected in the presence of the neomycin analogue G418 (Genitacin, 1 mg/ml, Gibco). Viral supernatants are harvested after 48 hours from pools of G418 resistant helper cells and used to infect the amphotropic packaging cell line PA317 in the presence of 8 mg/ml polybrene. Clonal, high titer producer lines are derived by selection in 1.0 mg/ml G418 containing medium. Supernatants of these producer lines are used to infect C196 cells. Clones of infected cells selected for high expression of the scFv(FRP5):hinge:ζ DNA are derived and assayed for the production of chimeric cell surface proteins (Example 3). Clone CFYZ.1 is derived by growth in 1.0 mg/ml G418. Jurkat cells are infected using the same procedure, the clone JFYZ.4 is derived by growth in 2.0 mg/ml G418.

Example 3: Biochemical characterization of cell surface proteins

a) SDS-PAGE analysis of the chimeric scF(FRP5):hinge:ζ proteins produced by transduced CTL

Selected clones of Example 2 are cell surface biotinylated, lysed and immunoprecipitated with an anti-ζ mAb. For surface biotinylation, 3×10^7 viable cells are washed three times in biwa buffer (PBS, 1 mM $MgCl_2$, 0.1 mM $CaCl_2$) and resuspended in 1.5 ml Sulfo-NHS Biotin in biwa buffer (Pierce, 0.5 mg/ml). After incubating 15 min at 4°C, the reaction is quenched by addition of 25 mM L-lysine in biwa buffer. The cells are washed three times in quenching buffer (25 mM L-lysine in biwa buffer) and lysed in 1% NP-40, 150 mM NaCl, 50 mM Tris/HCL pH 8.0, 5 mM EDTA, 1 mM PMSF containing buffer supplemented with a protease inhibitor cocktail. Postnuclear lysates are precleared overnight with Protein A Sepharose (Pharmacia). Immunoprecipitation is performed by addition of 3 mg of the ζ-specific mAb H146-968 which recognizes human and mouse COOH terminus of the ζ chain, incubated for 3 hours followed by 1 hour incubation with Protein A Sepharose. The precipitate is washed four times in NET-TON (650 mM NaCl, 5 mM EDTA, 50 mM Tris/HCl, 0.5% Triton X-100, 1 mg/ml ovalbumin). For deglycosylation, precipitates are denatured in 5% SDS with or without 10%

2-mercaptoethanol at 100°C and incubated with 2.000 U PNGase F (Biolabs) for 1 hour at 37°C. Samples are boiled in either non-reducing or reducing Laemmli-sample buffer and electrophoresed through 5-20% SDS-PAGE gradient gels. The proteins are transferred to a PVDF membrane (Millipore) and blocked in PBS-T (PBS, 0.4% Tween-20) containing 5% skim milk powder (Fluka). The membrane is incubated for one hour with PBS-T containing horseradish peroxidase-streptavidin (HRP-Strep, Southern Biotechnology, 1:5.000). After washing the membrane four times for 7 min in PBS-T, the blot is developed using the ECL-chemoluminescence reagent (Amersham). The SDS-PAGE analysis of the immunoprecipitates under reducing conditions reveals a series of bands with an apparent molecular weight of about 48-65 kDa from lysates of infected cells (clone CFYZ.1), but not in lysates of the parental cells (C196 cells). The 48 kDa band corresponds to the scFv(FRP5):hinge:ζ protein with a calculated molecular weight of 48.7 kDa. The amino acid sequence of said protein is depicted in SEQ ID NO:5. In said sequence listing the recognition part derived from mAb FRP5 extends from the amino acid at position 6 (Gln) to the amino acid at position 240 (Ile), the hinge region derived from CD8α extends from the amino acid at position 245 (Ile) to the amino acid at position 304 (Phe) and the ζ chain extends from the amino acid at position 307 (Asp) to the amino acid at position 443 (Arg). The higher molecular weight species arise as a consequence of complex glycosylation of the scFv and the hinge region. Deglycosylation with the endoglycosidase PNGase F results in a simplified protein pattern and the reduction of the apparent molecular weight to about 47 kDa. The endogenous ζ-chain is detected as a 16 kDa band (16.3 kDa predicted) in uninfected and infected cells. When the SDS-PAGE analysis is carried out under non-reducing conditions, both disulfide-linked scFv:hinge:ζ homodimers with an apparent molecular weight of about 96 kDa as well as heterodimers of scFv(FRP5):hinge:ζ molecules with the endogenous ζ with an apparent molecular weight of about 64 kDa are observed. PNGase F treatment slightly reduced the molecular weights of these two bands. The detected 32 kDa band corresponds to endogenous ζ-ζ homodimers of the CTL.

b) Flow cytometric analysis of scFv(FRP5):hinge:ζ protein producing T cells

Cell surface expression and erbB-2 receptor binding ability of the scFv(FRP5):hinge:ζ protein in transduced C196 CTL and in transduced Jurkat cells are confirmed by flow cytometry.

Single-cell suspensions of 5×10^5 viable cells (Jurkat cells, JFYZ.4 cells, C196 cells, CFYZ.1 cells) are stained with the purified extracellular domain of the erbB-2 protein (erbB-2^{ecd}, expressed in Sf9 insect cells using a baculovirus expression vector; Disis et

al., Cancer Res. 54, 16-20 (1994)) for 1 hour followed by the FITC-conjugated anti-erbB-2 monoclonal antibody FSP77 (European patent application EP-A-502 812) for 45 min at 4°C in 100 µl PBS containing 1% BSA and 0.1% sodium azide. FSP77 also is specific for the extracellular domain of the erbB-2 receptor, but recognizes a different epitope from mAb FRP5 (I.M. Harwerth et al., J. Biol. Chem. 21, 15160-15167 (1992)). Ten thousand forward scatter/side scatter gated viable cells are acquired and analysed with a flow cytometer revealing binding of the purified, soluble extracellular domain of the erbB-2 receptor to the transduced T cells JFYZ.4 and CFYZ.1 but not to non-infected Jurkat or C196 cells.

The hinge region provides flexibility and accessibility to the scFv moiety and is a necessary prerequisite for the binding of the extracellular domain of the erbB-2 receptor to the scFv domain. Insertion of the CD4 D3D4 also allows binding. A construct in which a direct fusion, without a hinge region or spacer, of the scFv domain to the ζ-chain is tested, results in a surface receptor which cannot bind to the erbB-2 protein.

Example 4: Signal transduction of the scFv(FRP5):hinge:ζ fusion protein

The intracellular calcium (Ca^{2+}) concentration of T cells loaded with a suitable calcium-chelating fluorescent dye is measured after incubation with the soluble erbB-2 receptor. For this purpose cultured JFYZ.4 infectants and Jurkat cells are suspended at $1 \times 10^7/\text{ml}$ in RPMI 1640 supplemented with 2% FCS and 5 mM Indo-1/AM (Calbiochem) (M. Lopez et al., Cytometry 10, 165-173 (1989)) and rotated for 45 min at 37°C. After washing twice, 3×10^5 cells are incubated on ice with 2 mg purified erbB-2^{ecd}.

Triggering is performed at 37°C by simultaneous administration of 5 mg anti-erbB-2 mAb FSP77 followed by crosslinking with a goat anti-mouse Ig antiserum (GαM Ig, Southern Biotechnology). As a control, cells are triggered by addition of anti-human CD3ε mAb (Serva) and GαM Ig. Calcium flux is monitored for 15 min on a flow cytometer by measuring emission at 405 and 525 nm.

Crosslinking results in a rapid increase of intracellular calcium in JFCZ.4 cells but not in parental Jurkat cells comparable to that obtained by crosslinking the CD3 complex with an anti-CD3ε mAb in non-infected cells. This indicates that intracellular signalling is triggered upon crosslinking of the scFv(FRP5):hinge:ζ protein via an extracellular ligand domain and that the scFv(FRP5):hinge:ζ protein is functionally active.

Example 5: In vitro cytotoxicity assay

The cytolytic activity of infected C196 (CFYZ.1) cells is determined in vitro.

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Oncogenically transformed mouse NIH/3T3 fibroblasts and HC11 epithelial cells expressing the human erbB-2 receptor (N.E. Hynes et al., supra) are employed as target cells. The release of LDH from these cells is used as a measure of cell lysis (T. Decker and M.L. Lohmann-Matthes, J. Immunol. Methods 115, 61-69 (1988)).

The cytotoxicity assay is performed in phenol red free medium supplied with 4% conditioned supernatant containing recombinant murine Il-2 (rmIl-2, see above). A constant number of target cells (7.500/well) is added to a serial 2-fold dilution of effectors (CFYZ.1 cells) followed by an eight hour incubation at 37°C and 5% CO₂. All dilutions are performed in triplicates. The LDH content of a 50 µl aliquot of the supernatant is assayed using the CytoTox 96 assay (Promega) (T. Decker and M.L. Lohmann-Matthes, supra). The LDH activity measured after lysis of target cells with 0.4% Triton X-100 is considered as 100%. The measured experimental values are corrected for the spontaneous release of LDH from effector and target cells. Infected C196 cells expressing the scFv(FRP5):hinge:ζ construct efficiently lyse erbB-2 expressing NIH/3T3 cells or HC11 cells at effector to target ratios between 1 and 10. Lysis of the epithelial and fibroblast target cells transfected with the human erbB-2 receptor occurs in a non MHC-restricted manner indistinguishable from normal antigen-specific cellular cytotoxicity. In contrast, no cell lysis is observed when the parental C196 cells are used as effectors. The mAb FRP5 and the derived scFv domain are specific for the human erbB-2 molecule and do not recognize the mouse homologue which is expressed at low levels on both cell lines. For this reason, no cell lysis is observed when untransfected NIH/3T3 cells or HC11 cells are incubated with the scFv(FRP5):hinge:ζ construct expressing T cells.

Example 6: In vivo anti-tumor activity

Two experimental schedules are used to assess the anti-tumor activity of the transduced CTL (infected C196 cells) in vivo. In the first schedule, 5×10^5 NIH3T3#3.7 tumor cells are mixed with 5×10^6 CFYZ.1 cells or parental C196 cells (effector to target ratio of 1:10) in 0.1 ml culture medium and immediately injected subcutaneously (s.c.) into the right flank of Balb/c nude mice (H.J. Winn, J. Immunol. 86, 228-234 (1961)). The growth of the tumors is followed by caliper measurements. NIH3T3#3.7 tumor cells alone are injected as a control. Each group consists of five animals. In the second schedule, Balb/c nude mice are inoculated s.c. into the right flank with 4×10^5 NIH3T3#3.7 tumor cells. On day 4 and 5, when tumors are palpable, parental C196 cells and CFYZ.1 cells are injected intravenously into the tail vein (1×10^7 cells in 0.2 ml culture medium). 500 U of rhIl-2 (Hoffmann-La Roche) in 0.2 ml PBS are administered intraperitoneally on days 4, 5 and 6. The growth of the tumors is followed by caliper measurements. NIH3T3#3.7 cells

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without Il-2 and with Il-2 are injected as controls. Each group consists of five animals. NIH/3T3 cells transformed with the human erbB-2 oncogene lead to the rapid formation of tumors after subcutaneous injection into athymic Balb/c nude mice. The simultaneous administration of CFYZ.1 infectants and tumor cells completely suppresses tumor formation for up to 7 days. Administration of the uninfected parental C196 cells, however has no effect on tumor cell growth. A similar result is obtained when nude mice are inoculated first with NIH/3T3-erbB-2 tumor cells and subsequently treated with CFYZ.1 cells in combination with exogenous Il- 2. The administration of the transduced CTL strongly retards the growth of the tumor cells over a course of seven days thus showing a systemic in vivo effect. The cells have the capability to home the tumor, to be activated and display their cytolytic activity when administered at a different site.

These results show that the specificity and thus the cytolytic effector machinery of the transduced CTL can be efficiently redirected towards a predefined surface antigen, the erbB-2 receptor, which plays an important role in the etiology of many human adenocarcinomas including breast, ovarian, gastric and colon cancer. Therefore the principle of targeted T cell action is conceived as a useful therapy approach and generally applicable for the elimination of tumor cells which express a surface antigen at higher levels than normal cells. The design permits the generation of CTL with many desired specificities by exchanging the scFv moiety and replacing it with any existing antigen recognition function derived from a specific monoclonal antibody. The use of efficient transfer systems, e.g. retroviral vectors, allows the transfer of scFv:hinge:ζ DNAs into cell types which are not easily transfectable.

Deposition data:

Hybridoma cell lines producing antibodies FRP5, FSP16, FSP77 and FWP51 have been deposited with the European Collection of Animal Cell Cultures (ECACC, PHLS Centre for Applied Microbiology & Research, Porton Down, Salisbury, UK) on November 21, 1990 under accession numbers 90112115, 90112116, 90112117 and 90112118, respectively.

Brief Description of the Figure:

Figure 1: Structure of the pL(F4Z)SN retroviral vector. A cDNA encoding amino acid residues number 184 - 370 of the CD 4 immunoglobulin like D3 and D4 domains is derived by PCR and subcloned into the XbaI site of the PL(FX)SN vector. Amino acid sequences of the fusion boundaries are shown in the single letter code.

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

(A) NAME: CIBA-GEIGY AG
 (B) STREET: Klybeckstr. 141
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 (H) TELEFAX: + 41 61 696 79 76
 (I) TELEX: 962 991

(ii) TITLE OF INVENTION: Bifunctional Protein, Preparation and Use

(iii) NUMBER OF SEQUENCES: 11

(iv) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk
 (B) COMPUTER: IBM PC compatible
 (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 (D) SOFTWARE: PatentIn Release #1.0, Version #1.25 (EPO)

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 748 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: CDS
 (B) LOCATION: 9..728
 (D) OTHER INFORMATION: /product= "scFv(FRP)5"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

AAGCTTCT CAG GTA CAA CTG CAG CAG TCT GGA CCT GAA CTG AAG AAG CCT
 Gln Val Gln Leu Gln Gln Ser Gly Pro Glu Leu Lys Lys Pro
 1 5 10

50

- 24 -

GGA Gly 15	GAG Glu	ACA Thr	GTC Val	AAG Lys	ATC Ile	TCC Ser	TGC Cys	AAG Lys	GCC Ala	TCT Ser	GGG Gly	TAT Tyr	CCT Pro	TTC Phe	ACA Thr	98
AAC Asn	TAT Tyr	GGA Gly	ATG Met	AAC Asn	TGG Trp	GTG Val	AAG Lys	CAG Gln	GCT Ala	CCA Pro	GGA Gly	CAG Gln	GGT Gly	TTA Leu	AAG Lys	146
TGG Trp	ATG Met	GGC Gly	TGG Trp	ATT Ile	AAC Asn	ACT Thr	TCC Ser	ACT Thr	GGA Gly	GAG Glu	TCA Ser	ACA Thr	TTT Phe	GCT Ala	GAT Asp	194
GAC Asp	TTC Phe	AAG Lys	GGA Gly	CGG Arg	TTT Phe	GAC Asp	TTC Phe	TCT Ser	TTG Leu	GAA Glu	ACC Thr	TCT Ser	GCC Ala	AAC Asn	ACT Thr	242
GCC Ala	TAT Tyr	TTG Leu	CAG Gln	ATC Ile	AAC Asn	AAC Asn	CTC Leu	AAA Lys	AGT Ser	GAA Glu	GAC Asp	ATG Met	GCT Ala	ACA Thr	TAT Tyr	290
TTC Phe	TGT Cys	GCA Ala	AGA Arg	TGG Trp	GAG Glu	GTT Val	TAC Tyr	CAC His	GGC Gly	TAC Tyr	GTT Val	CCT Pro	TAC Tyr	TGG Trp	GGC Gly	338
CAA Gln	GGG Gly	ACC Thr	ACG Thr	GTC Val	ACC Thr	GTT Val	TCC Ser	TCT Ser	GGC Gly	GGT Gly	GGC Gly	GGT Gly	TCT Ser	GGT Gly	GGC Gly	386
GGT Gly	GGC Gly	TCC Ser	GGC Gly	GGT Gly	GGC Gly	GGT Gly	TCT Ser	GAC Asp	ATC Ile	CAG Gln	CTG Leu	ACC Thr	CAG Gln	TCT Ser	CAC His	434
AAA Lys	TTC Phe	CTG Leu	TCC Ser	ACT Thr	TCA Ser	GTA Val	GGA Gly	GAC Asp	AGG Arg	GTC Val	AGC Ser	ATC Ile	ACC Thr	TGC Cys	AAG Lys	482
GCC Ala	AGT Ser	CAG Gln	GAT Asp	GTG Val	TAT Tyr	AAT Asn	GCT Ala	GTT Val	GCC Ala	TGG Trp	TAT Tyr	CAA Gln	CAG Gln	AAA Lys	CCA Pro	530
GGA Gly	CAA Gln	TCT Ser	CCT Pro	AAA Lys	CTT Leu	CTG Leu	ATT Ile	TAC Tyr	TCG Ser	GCA Ala	TCC Ser	TCC Ser	CGG Arg	TAC Tyr	ACT Thr	578
GGA Gly	GTC Val	CCT Pro	TCT Ser	CGC Arg	TTC Phe	ACT Thr	GGC Gly	AGT Ser	GGC Gly	TCT Ser	GGG Gly	CCG Pro	GAT Asp	TTC Phe	ACT Thr	626
TTC Phe	ACC Thr	ATC Ile	AGC Ser	AGT Ser	GTG Val	CAG Gln	GCT Ala	GAA Glu	GAC Asp	CTG Leu	GCA Ala	GTT Val	TAT Tyr	TTC Phe	TGT Cys	674

CAG CAA CAT TTT CGT ACT CCA TTC ACG TTC GGC TCG GGG ACA AAA TTG 722
Gln Gln His Phe Arg Thr Pro Phe Thr Phe Gly Ser Gly Thr Lys Leu
225 230 235

GAG ATC TAGCTGATCA AAGCTCTAGA 748
Glu Ile
240

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 240 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEO ID NO: 2:

Gln 1	Val	Gln	Leu	Gln 5	Gln	Ser	Gly	Pro	Glu 10	Leu	Lys	Lys	Pro	Gly 15	Glu
Thr	Val	Lys	Ile 20	Ser	Cys	Lys	Ala	Ser 25	Gly	Tyr	Pro	Phe	Thr 30	Asn	Tyr
Gly	Met	Asn 35	Trp	Val	Lys	Gln	Ala 40	Pro	Gly	Gln	Gly	Leu 45	Lys	Trp	Met
Gly	Trp 50	Ile	Asn	Thr	Ser	Thr 55	Gly	Glu	Ser	Thr	Phe 60	Ala	Asp	Asp	Phe
Lys 65	Gly	Arg	Phe	Asp	Phe 70	Ser	Leu	Glu	Thr	Ser 75	Ala	Asn	Thr	Ala	Tyr 80
Leu	Gln	Ile	Asn	Asn 85	Leu	Lys	Ser	Glu	Asp 90	Met	Ala	Thr	Tyr	Phe 95	Cys
Ala	Arg	Trp	Glu 100	Val	Tyr	His	Gly	Tyr 105	Val	Pro	Tyr	Trp	Gly 110	Gln	Gly
Thr	Thr	Val 115	Thr	Val	Ser	Ser	Gly 120	Gly	Gly	Gly	Ser	Gly 125	Gly	Gly	Gly
Ser	Gly 130	Gly	Gly	Gly	Ser	Asp 135	Ile	Gln	Leu	Thr	Gln 140	Ser	His	Lys	Phe
Leu 145	Ser	Thr	Ser	Val	Gly 150	Asp	Arg	Val	Ser	Ile 155	Thr	Cys	Lys	Ala	Ser 160
Gln	Asp	Val	Tyr	Asn 165	Ala	Val	Ala	Trp	Tyr 170	Gln	Gln	Lys	Pro	Gly 175	Gln

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Ser	Pro	Lys	Leu	Leu	Ile	Tyr	Ser	Ala	Ser	Ser	Arg	Tyr	Thr	Gly	Val
			180					185					190		
Pro	Ser	Arg	Phe	Thr	Gly	Ser	Gly	Ser	Gly	Pro	Asp	Phe	Thr	Phe	Thr
		195					200					205			
Ile	Ser	Ser	Val	Gln	Ala	Glu	Asp	Leu	Ala	Val	Tyr	Phe	Cys	Gln	Gln
	210					215					220				
His	Phe	Arg	Thr	Pro	Phe	Thr	Phe	Gly	Ser	Gly	Thr	Lys	Leu	Glu	Ile
225					230					235					240

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 748 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
(B) LOCATION: 9..728
(D) OTHER INFORMATION: /product= "scFv (FWP51)"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

AAGCTTCT	CAG	GTA	CAA	CTG	CAG	CAG	TCT	GGG	GCT	GAG	CTG	GTG	AGG	CCT		50
	Gln	Val	Gln	Leu	Gln	Gln	Ser	Gly	Ala	Glu	Leu	Val	Arg	Pro		
	1				5					10						
GGG ACT TCA GTG AAG CTG TCC TGC AAG GCT TCT GAT TAC ACC TTC ACC																98
Gly Thr Ser Val Lys Leu Ser Cys Lys Ala Ser Asp Tyr Thr Phe Thr																
15				20				25						30		
AGC TAC TGG ATG AAC TGG GTG AAG CAG AGG CCT GGA CAA GGC CTT GAA																146
Ser Tyr Trp Met Asn Trp Val Lys Gln Arg Pro Gly Gln Gly Leu Glu																
			35					40						45		
TGG ATT GGT ATG ATT GAT CCT TCA GAC AGT GAA ACT CAA TAC AAT CAA																194
Trp Ile Gly Met Ile Asp Pro Ser Asp Ser Glu Thr Gln Tyr Asn Gln																
			50					55					60			
ATG TTC AAG GAC AAG GCC GCA TTG ACT GTA GAC AAG TCC TCC AAT ACA																242
Met Phe Lys Asp Lys Ala Ala Leu Thr Val Asp Lys Ser Ser Asn Thr																
		65					70					75				

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GCC TAC ATG CAA CTC AGC AGC CTG ACA TCT GAG GAC TCT GCG GTC TAT	290
Ala Tyr Met Gln Leu Ser Ser Leu Thr Ser Glu Asp Ser Ala Val Tyr	
80 85 90	
TAC TGT GCA AAA GGG GGG GCC TCT GGG GAC TGG TAC TTC GAT GTC TGG	338
Tyr Cys Ala Lys Gly Gly Ala Ser Gly Asp Trp Tyr Phe Asp Val Trp	
95 100 105 110	
GGC CAA GGG ACC ACG GTC ACC GTT TCC TCT GGC GGT GGC GGT TCT GGT	386
Gly Gln Gly Thr Thr Val Thr Val Ser Ser Gly Gly Gly Gly Ser Gly	
115 120 125	
GGC GGT GGC TCC GGC GGT GGC GGT TCT GAC ATC CAG CTG ACC CAG TCT	434
Gly Gly Gly Ser Gly Gly Gly Gly Ser Asp Ile Gln Leu Thr Gln Ser	
130 135 140	
CCA TCC TCA CTG TCT GCA TCT CTG GGA GGC GAA GTC ACC ATC ACT TGC	482
Pro Ser Ser Leu Ser Ala Ser Leu Gly Gly Glu Val Thr Ile Thr Cys	
145 150 155	
AAG GCA AGC CAA GAC ATT AAG AAG TAT ATA GCT TGG TAC CAA CAC AAG	530
Lys Ala Ser Gln Asp Ile Lys Lys Tyr Ile Ala Trp Tyr Gln His Lys	
160 165 170	
CCT GGA AAA AGT CCT CGG CTA CTC ATA CAC TAC ACA TCT GTA TTA CAG	578
Pro Gly Lys Ser Pro Arg Leu Leu Ile His Tyr Thr Ser Val Leu Gln	
175 180 185 190	
CCA GGC ATC CCA TCC AGG TTC AGT GGA AGT GGG TCT GGG AGA GAT TAT	626
Pro Gly Ile Pro Ser Arg Phe Ser Gly Ser Gly Ser Gly Arg Asp Tyr	
195 200 205	
TCC TTC AGC ATC CAC AAC CTG GAG CCT GAA GAT ATT GCA ACT TAT TAT	674
Ser Phe Ser Ile His Asn Leu Glu Pro Glu Asp Ile Ala Thr Tyr Tyr	
210 215 220	
TGT CTA CAT TAT GAT TAT CTG TAC ACG TTC GGA GGG GGC ACC AAG CTG	722
Cys Leu His Tyr Asp Tyr Leu Tyr Thr Phe Gly Gly Gly Thr Lys Leu	
225 230 235	
GAG ATC TAGCTGATCA AAGCTCTAGA	748
Glu Ile	
240	

(2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 240 amino acids
 - (B) TYPE: amino acid
 - (D) TOPOLOGY: linear

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(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

Gln Val Gln Leu Gln Gln Ser Gly Ala Glu Leu Val Arg Pro Gly Thr
 1 5 10 15
 Ser Val Lys Leu Ser Cys Lys Ala Ser Asp Tyr Thr Phe Thr Ser Tyr
 20 25 30
 Trp Met Asn Trp Val Lys Gln Arg Pro Gly Gln Gly Leu Glu Trp Ile
 35 40 45
 Gly Met Ile Asp Pro Ser Asp Ser Glu Thr Gln Tyr Asn Gln Met Phe
 50 55 60
 Lys Asp Lys Ala Ala Leu Thr Val Asp Lys Ser Ser Asn Thr Ala Tyr
 65 70 75 80
 Met Gln Leu Ser Ser Leu Thr Ser Glu Asp Ser Ala Val Tyr Tyr Cys
 85 90 95
 Ala Lys Gly Gly Ala Ser Gly Asp Trp Tyr Phe Asp Val Trp Gly Gln
 100 105 110
 Gly Thr Thr Val Thr Val Ser Ser Gly Gly Gly Gly Ser Gly Gly Gly
 115 120 125
 Gly Ser Gly Gly Gly Gly Ser Asp Ile Gln Leu Thr Gln Ser Pro Ser
 130 135 140
 Ser Leu Ser Ala Ser Leu Gly Gly Glu Val Thr Ile Thr Cys Lys Ala
 145 150 155 160
 Ser Gln Asp Ile Lys Lys Tyr Ile Ala Trp Tyr Gln His Lys Pro Gly
 165 170 175
 Lys Ser Pro Arg Leu Leu Ile His Tyr Thr Ser Val Leu Gln Pro Gly
 180 185 190
 Ile Pro Ser Arg Phe Ser Gly Ser Gly Ser Gly Arg Asp Tyr Ser Phe
 195 200 205
 Ser Ile His Asn Leu Glu Pro Glu Asp Ile Ala Thr Tyr Tyr Cys Leu
 210 215 220
 His Tyr Asp Tyr Leu Tyr Thr Phe Gly Gly Gly Thr Lys Leu Glu Ile
 225 230 235 240

(2) INFORMATION FOR SEQ ID NO: 5:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 1479 base pairs

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- (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
 (B) LOCATION: 40..1422
 (D) OTHER INFORMATION: /product= "leader-scFv(FRP5):lyt-2
 hinge:zeta"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

GAATTCGGCA CGAGCTTAAG GCACCACTTC TTAGACATC ATG GCT TGG GTG TGG	54
Met Ala Trp Val Trp	
1 5	
ACC TTG CTA TTC CTG ATG GCA GCT GCC AAA GTG CCC AAG CAG ATC CAG	102
Thr Leu Leu Phe Leu Met Ala Ala Lys Val Pro Lys Gln Ile Gln	
10 15 20	
TTG GTG CAG TCT GGA CCT GAG CTG AAG AAG CCT GGA GAG ACA GTC AAG	150
Leu Val Gln Ser Gly Pro Glu Leu Lys Lys Pro Gly Glu Thr Val Lys	
25 30 35	
ATC TCC TGC AAG GCC TCT GGG TAT CCT TTC ACA AAC TAT GGA ATG AAC	198
Ile Ser Cys Lys Ala Ser Gly Tyr Pro Phe Thr Asn Tyr Gly Met Asn	
40 45 50	
TGG GTG AAG CAG GCT CCA GGA CAG GGT TTA AAG TGG ATG GGC TGG ATT	246
Trp Val Lys Gln Ala Pro Gly Gln Gly Leu Lys Trp Met Gly Trp Ile	
55 60 65	
AAC ACC TCC ACT GGA GAG TCA ACA TTT GCT GAT GAC TTC AAG GGA CGG	294
Asn Thr Ser Thr Gly Glu Ser Thr Phe Ala Asp Asp Phe Lys Gly Arg	
70 75 80 85	
TTT GAC TTC TCT TTG GAA ACC TCT GCC AAC ACT GCC TAT TTG CAG ATC	342
Phe Asp Phe Ser Leu Glu Thr Ser Ala Asn Thr Ala Tyr Leu Gln Ile	
90 95 100	
AAC AAC CTC AAA AGT GAA GAC ATG GCT ACA TAT TTC TGT GCA AGA TGG	390
Asn Asn Leu Lys Ser Glu Asp Met Ala Thr Tyr Phe Cys Ala Arg Trp	
105 110 115	
GAG GTT TAC CAC GGC TAC GTT CCT TAC TGG GGC CAA GGG ACC ACG GTC	438
Glu Val Tyr His Gly Tyr Val Pro Tyr Trp Gly Gln Gly Thr Thr Val	
120 125 130	

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ACC GTT TCC TCT GGC GGT GGC GGT TCT GGT GGC GGT GGC TCC GGC GGT	486
Thr Val Ser Ser Gly Gly Gly Gly Ser Gly Gly Gly Gly Ser Gly Gly	
135 140 145	
GGC GGT TCT GAC ATC CAG CTG ACC CAG TCT CAC AAA TTC CTG TCC ACT	534
Gly Gly Ser Asp Ile Gln Leu Thr Gln Ser His Lys Phe Leu Ser Thr	
150 155 160 165	
TCA GTA GGA GAC AGG GTC AGC ATC ACC TGC AAG GCC AGT CAG GAT GTG	582
Ser Val Gly Asp Arg Val Ser Ile Thr Cys Lys Ala Ser Gln Asp Val	
170 175 180	
TAT AAT GCT GTT GCC TGG TAT CAA CAG AAA CCA GGA CAA TCT CCT AAA	630
Tyr Asn Ala Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Ser Pro Lys	
185 190 195	
CTT CTG ATT TAC TCG GCA TCC TCC CGG TAC ACT GGA GTC CCT TCT CGC	678
Leu Leu Ile Tyr Ser Ala Ser Ser Arg Tyr Thr Gly Val Pro Ser Arg	
200 205 210	
TTC ACT GGC AGT GGC TCT GGG CCG GAT TTC ACT TTC ACC ATC AGC AGT	726
Phe Thr Gly Ser Gly Ser Gly Pro Asp Phe Thr Phe Thr Ile Ser Ser	
215 220 225	
GTG CAG GCT GAA GAC CTG GCA GTT TAT TTC TGT CAG CAA CAT TTT CGT	774
Val Gln Ala Glu Asp Leu Ala Val Tyr Phe Cys Gln Gln His Phe Arg	
230 235 240 245	
ACT CCA TTC ACG TTC GGC TCG GGG ACA AAA TTG GAG ATC AAA GCT CTA	822
Thr Pro Phe Thr Phe Gly Ser Gly Thr Lys Leu Glu Ile Lys Ala Leu	
250 255 260	
GAG ATC AGC AAC TCG GTG ATG TAC TTC AGT TCT GTC GTG CCA GTC CTT	870
Glu Ile Ser Asn Ser Val Met Tyr Phe Ser Ser Val Val Pro Val Leu	
265 270 275	
CAG AAA GTG AAC TCT ACT ACT ACC AAG CCA GTG CTG CGA ACT CCC TCA	918
Gln Lys Val Asn Ser Thr Thr Thr Lys Pro Val Leu Arg Thr Pro Ser	
280 285 290	
CCT GTG CAC CCT ACC GGG ACA TCT CAG CCC CAG AGA CCA GAA GAT TGT	966
Pro Val His Pro Thr Gly Thr Ser Gln Pro Gln Arg Pro Glu Asp Cys	
295 300 305	
CGG CCC CGT GGC TCA GTG AAG GGG ACC GGA TTG GAC TTT CTA GAG GAT	1014
Arg Pro Arg Gly Ser Val Lys Gly Thr Gly Leu Asp Phe Leu Glu Asp	
310 315 320 325	
CCC AAA CTC TGC TAC TTG CTA GAT GGA ATC CTC TTC ATC TAC GGA GTC	1062
Pro Lys Leu Cys Tyr Leu Leu Asp Gly Ile Leu Phe Ile Tyr Gly Val	
330 335 340	

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ATC ATC ACA GCC CTG TAC CTG AGA GCA AAA TTC AGC AGG AGT GCA GAG Ile Ile Thr Ala Leu Tyr Leu Arg Ala Lys Phe Ser Arg Ser Ala Glu 345 350 355	1110
ACT GCT GCC AAC CTG CAG GAC CCC AAC CAG CTC TAC AAT GAG CTC AAT Thr Ala Ala Asn Leu Gln Asp Pro Asn Gln Leu Tyr Asn Glu Leu Asn 360 365 370	1158
CTA GGG CGA AGA GAG GAA TAT GAC GTC TTG GAG AAG AAG CGG GCT CGG Leu Gly Arg Arg Glu Glu Tyr Asp Val Leu Glu Lys Lys Arg Ala Arg 375 380 385	1206
GAT CCA GAG ATG GGA GGC AAA CAG CAG AGG AGG AGG AAC CCC CAG GAA Asp Pro Glu Met Gly Gly Lys Gln Gln Arg Arg Arg Asn Pro Gln Glu 390 395 400 405	1254
GGC GTA TAC AAT GCA CTG CAG AAA GAC AAG ATG GCA GAA GCC TAC AGT Gly Val Tyr Asn Ala Leu Gln Lys Asp Lys Met Ala Glu Ala Tyr Ser 410 415 420	1302
GAG ATC GGC ACA AAA GGC GAG AGG CGG AGA GGC AAG GGG CAC GAT GGC Glu Ile Gly Thr Lys Gly Glu Arg Arg Arg Gly Lys Gly His Asp Gly 425 430 435	1350
CTT TAC CAG GGT CTC AGC ACT GCC ACC AAG GAC ACC TAT GAT GCC CTG Leu Tyr Gln Gly Leu Ser Thr Ala Thr Lys Asp Thr Tyr Asp Ala Leu 440 445 450	1398
CAT ATG CAG ACC CTG GCC CCT CGC TAACAGCCAG GGCATTTCTC CCTCACGGGC His Met Gln Thr Leu Ala Pro Arg 455 460	1452
AGATCCCCGG GTACCGAGCT CGAATTC	1479

(2) INFORMATION FOR SEQ ID NO: 6:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 461 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

Met	Ala	Trp	Val	Trp	Thr	Leu	Leu	Phe	Leu	Met	Ala	Ala	Ala	Lys	Val
1				5					10					15	
Pro	Lys	Gln	Ile	Gln	Leu	Val	Gln	Ser	Gly	Pro	Glu	Leu	Lys	Lys	Pro
			20					25					30		
Gly	Glu	Thr	Val	Lys	Ile	Ser	Cys	Lys	Ala	Ser	Gly	Tyr	Pro	Phe	Thr
		35					40					45			

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Asn Tyr Gly Met Asn Trp Val Lys Gln Ala Pro Gly Gln Gly Leu Lys
 50 55 60

Trp Met Gly Trp Ile Asn Thr Ser Thr Gly Glu Ser Thr Phe Ala Asp
 65 70 75 80

Asp Phe Lys Gly Arg Phe Asp Phe Ser Leu Glu Thr Ser Ala Asn Thr
 85 90 95

Ala Tyr Leu Gln Ile Asn Asn Leu Lys Ser Glu Asp Met Ala Thr Tyr
 100 105 110

Phe Cys Ala Arg Trp Glu Val Tyr His Gly Tyr Val Pro Tyr Trp Gly
 115 120 125

Gln Gly Thr Thr Val Thr Val Ser Ser Gly Gly Gly Gly Ser Gly Gly
 130 135 140

Gly Gly Ser Gly Gly Gly Gly Ser Asp Ile Gln Leu Thr Gln Ser His
 145 150 155 160

Lys Phe Leu Ser Thr Ser Val Gly Asp Arg Val Ser Ile Thr Cys Lys
 165 170 175

Ala Ser Gln Asp Val Tyr Asn Ala Val Ala Trp Tyr Gln Gln Lys Pro
 180 185 190

Gly Gln Ser Pro Lys Leu Leu Ile Tyr Ser Ala Ser Ser Arg Tyr Thr
 195 200 205

Gly Val Pro Ser Arg Phe Thr Gly Ser Gly Ser Gly Pro Asp Phe Thr
 210 215 220

Phe Thr Ile Ser Ser Val Gln Ala Glu Asp Leu Ala Val Tyr Phe Cys
 225 230 235 240

Gln Gln His Phe Arg Thr Pro Phe Thr Phe Gly Ser Gly Thr Lys Leu
 245 250 255

Glu Ile Lys Ala Leu Glu Ile Ser Asn Ser Val Met Tyr Phe Ser Ser
 260 265 270

Val Val Pro Val Leu Gln Lys Val Asn Ser Thr Thr Thr Lys Pro Val
 275 280 285

Leu Arg Thr Pro Ser Pro Val His Pro Thr Gly Thr Ser Gln Pro Gln
 290 295 300

Arg Pro Glu Asp Cys Arg Pro Arg Gly Ser Val Lys Gly Thr Gly Leu
 305 310 315 320

Asp Phe Leu Glu Asp Pro Lys Leu Cys Tyr Leu Leu Asp Gly Ile Leu
 325 330 335

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Phe Ile Tyr Gly Val Ile Ile Thr Ala Leu Tyr Leu Arg Ala Lys Phe
 340 345 350
 Ser Arg Ser Ala Glu Thr Ala Ala Asn Leu Gln Asp Pro Asn Gln Leu
 355 360 365
 Tyr Asn Glu Leu Asn Leu Gly Arg Arg Glu Glu Tyr Asp Val Leu Glu
 370 375 380
 Lys Lys Arg Ala Arg Asp Pro Glu Met Gly Gly Lys Gln Gln Arg Arg
 385 390 395 400
 Arg Asn Pro Gln Glu Gly Val Tyr Asn Ala Leu Gln Lys Asp Lys Met
 405 410 415
 Ala Glu Ala Tyr Ser Glu Ile Gly Thr Lys Gly Glu Arg Arg Arg Gly
 420 425 430
 Lys Gly His Asp Gly Leu Tyr Gln Gly Leu Ser Thr Ala Thr Lys Asp
 435 440 445
 Thr Tyr Asp Ala Leu His Met Gln Thr Leu Ala Pro Arg
 450 455 460

(2) INFORMATION FOR SEQ ID NO: 7:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 443 amino acids
 - (B) TYPE: amino acid
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

Gln Ile Gln Leu Val Gln Ser Gly Pro Glu Leu Lys Lys Pro Gly Glu
 1 5 10 15
 Thr Val Lys Ile Ser Cys Lys Ala Ser Gly Tyr Pro Phe Thr Asn Tyr
 20 25 30
 Gly Met Asn Trp Val Lys Gln Ala Pro Gly Gln Gly Leu Lys Trp Met
 35 40 45
 Gly Trp Ile Asn Thr Ser Thr Gly Glu Ser Thr Phe Ala Asp Asp Phe
 50 55 60
 Lys Gly Arg Phe Asp Phe Ser Leu Glu Thr Ser Ala Asn Thr Ala Tyr
 65 70 75 80

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Leu	Gln	Ile	Asn	Asn	Leu	Lys	Ser	Glu	Asp	Met	Ala	Thr	Tyr	Phe	Cys	
				85					90					95		
Ala	Arg	Trp	Glu	Val	Tyr	His	Gly	Tyr	Val	Pro	Tyr	Trp	Gly	Gln	Gly	
			100				105				110					
Thr	Thr	Val	Thr	Val	Ser	Ser	Gly	Gly	Gly	Gly	Ser	Gly	Gly	Gly	Gly	
		115					120					125				
Ser	Gly	Gly	Gly	Gly	Ser	Asp	Ile	Gln	Leu	Thr	Gln	Ser	His	Lys	Phe	
		130					135					140				
Leu	Ser	Thr	Ser	Val	Gly	Asp	Arg	Val	Ser	Ile	Thr	Cys	Lys	Ala	Ser	
				145			150			155						160
Gln	Asp	Val	Tyr	Asn	Ala	Val	Ala	Trp	Tyr	Gln	Gln	Lys	Pro	Gly	Gln	
			165				170						175			
Ser	Pro	Lys	Leu	Leu	Ile	Tyr	Ser	Ala	Ser	Ser	Arg	Tyr	Thr	Gly	Val	
		180					185					190				
Pro	Ser	Arg	Phe	Thr	Gly	Ser	Gly	Ser	Gly	Pro	Asp	Phe	Thr	Phe	Thr	
		195					200					205				
Ile	Ser	Ser	Val	Gln	Ala	Glu	Asp	Leu	Ala	Val	Tyr	Phe	Cys	Gln	Gln	
		210					215					220				
His	Phe	Arg	Thr	Pro	Phe	Thr	Phe	Gly	Ser	Gly	Thr	Lys	Leu	Glu	Ile	
				225			230			235						240
Lys	Ala	Leu	Glu	Ile	Ser	Asn	Ser	Val	Met	Tyr	Phe	Ser	Ser	Val	Val	
			245					250					255			
Pro	Val	Leu	Gln	Lys	Val	Asn	Ser	Thr	Thr	Thr	Lys	Pro	Val	Leu	Arg	
		260					265					270				
Thr	Pro	Ser	Pro	Val	His	Pro	Thr	Gly	Thr	Ser	Gln	Pro	Gln	Arg	Pro	
		275					280					285				
Glu	Asp	Cys	Arg	Pro	Arg	Gly	Ser	Val	Lys	Gly	Thr	Gly	Leu	Asp	Phe	
		290					295					300				
Leu	Glu	Asp	Pro	Lys	Leu	Cys	Tyr	Leu	Leu	Asp	Gly	Ile	Leu	Phe	Ile	
				305			310			315						320
Tyr	Gly	Val	Ile	Ile	Thr	Ala	Leu	Tyr	Leu	Arg	Ala	Lys	Phe	Ser	Arg	
			325						330					335		
Ser	Ala	Glu	Thr	Ala	Ala	Asn	Leu	Gln	Asp	Pro	Asn	Gln	Leu	Tyr	Asn	
		340					345					350				
Glu	Leu	Asn	Leu	Gly	Arg	Arg	Glu	Glu	Tyr	Asp	Val	Leu	Glu	Lys	Lys	
		355					360					365				

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Arg Ala Arg Asp Pro Glu Met Gly Gly Lys Gln Gln Arg Arg Arg Asn
 370 375 380
 Pro Gln Glu Gly Val Tyr Asn Ala Leu Gln Lys Asp Lys Met Ala Glu
 385 390 395 400
 Ala Tyr Ser Glu Ile Gly Thr Lys Gly Glu Arg Arg Arg Gly Lys Gly
 405 410 415
 His Asp Gly Leu Tyr Gln Gly Leu Ser Thr Ala Thr Lys Asp Thr Tyr
 420 425 430
 Asp Ala Leu His Met Gln Thr Leu Ala Pro Arg
 435 440

(2) INFORMATION FOR SEQ ID NO: 8:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 41 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

CTGAAAGCTT AGATCTGCCC GTGAGGGAGA AATGCCCTGG C

41

(2) INFORMATION FOR SEQ ID NO: 9:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 35 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

TCGATCTAGA AAGTCCAATC CGGTCCCCTT CACTG

35

(2) INFORMATION FOR SEQ ID NO: 10:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 33 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

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(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

GATCTCTAGA GGATCCCAA CTCTGCTACT TGC

33

(2) INFORMATION FOR SEQ ID NO: 11:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 37 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

TCGATCTAGA GATCAGCAAC TCGGTGATGT ACTTCAG

37

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Claims

1. A bifunctional protein comprising:
 - 1) an antigen binding domain derivable from a monoclonal antibody directed against a suitable antigen on a tumor cell,
 - 2) a hinge region comprising from about 40 to about 200 amino acids, and
 - 3) a functional zeta (ζ) chain derivable from the T-cell antigen receptor (TCR).
2. A DNA encoding a bifunctional protein comprising:
 - 1) an antigen binding domain derivable from a monoclonal antibody directed against a suitable antigen on a tumor cell,
 - 2) a hinge region comprising from about 40 to about 200 amino acids, and
 - 3) a functional zeta (ζ) chain derivable from the T-cell antigen receptor (TCR).
3. A DNA according to claim 2 encoding a protein wherein the antigen binding domain is a single chain antibody, particularly the single chain antibody designated FRP5 (scFv(FRP5)).
4. A DNA according to claim 2 or 3 encoding a protein wherein the hinge region is an immunoglobulin-like hinge region.
5. A DNA according to claims 2 to 4 encoding a protein wherein the functional ζ chain comprises the transmembrane and the cytoplasmic domain.
6. A host cell expressing the DNA of any of claims 2 to 5.
7. A host cell according to claim 6 which is a cytotoxic lymphocyte (CTL).
8. A process for lysing selected tumor cells comprising contacting said tumor cells with CTL producing the protein of claim 1.
9. A process for endowing a CTL with a defined, MHC-independent and MHC-unrestricted tumor cell specificity comprising introducing into said CTL a DNA according to claims 2 to 4.
10. A method for the production of a protein according to claim 1 comprising culturing a

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host cell of claim 6 under conditions which allow the expression of a DNA encoding said protein.

11. A composition-of-matter comprising a host cell according to claim 6 or 7.
12. A method of treating cancer comprising the use of a host cell according to claim 7.
13. CTL according to claim 7 for use in a method of treating cancer.
14. Polyclonal or monoclonal antibody specific for a protein according to claim 1.
15. Vector comprising a DNA according to claims 2 to 5

1 / 1

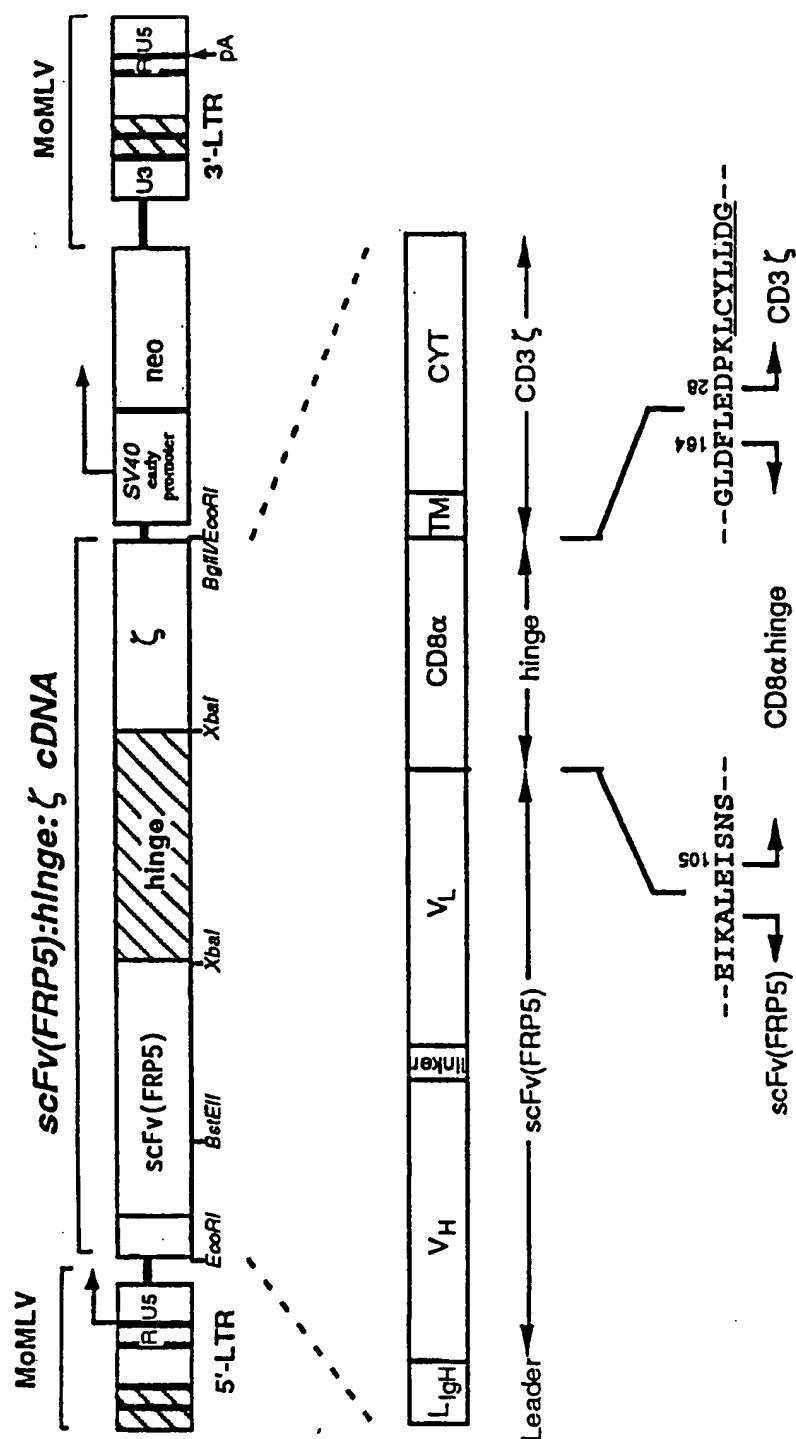


Figure 1 Structure of the pL(FYZ)SN retroviral vector.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 95/01494

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C12N15/62 C07K19/00 C12N5/10 C12P21/00 A61K35/14
C12P21/08 C12N15/85

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N C07K C12P A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO-A-92 10591 (CELL GENESYS, INC. & THE REGENTS OF THE UNIVERSITY OF CALIFORNIA) 25 June 1992 see page 4, line 26 - page 8, line 7 see page 16, line 16 - line 21 see claims 1-3, 10-12, 17-19, 22-25 ---	1,2, 4-13, 15
Y	THE JOURNAL OF IMMUNOLOGY, vol. 151, no. 11, 1 December 1993 BALTIMORE MD, USA, pages 6577-6582, I. STANCOVSKI ET AL. 'Targeting of T lymphocytes to Neu/HER2-expressing cells using chimeric single chain Fv receptors.' see the whole document --- -/--	1-15

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
 E earlier document but published on or after the international filing date
 L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 O document referring to an oral disclosure, use, exhibition or other means
 P document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
 & document member of the same patent family

Date of the actual completion of the international search

28 August 1995

Date of mailing of the international search report

05.09.95

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Authorized officer

Nooij, F

INTERNATIONAL SEARCH REPORT

Internat'l Application No

PCT/EP 95/01494

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	INTERNATIONAL IMMUNOLOGY, vol. 4, no. 2, February 1992 OXFORD, GB, pages 215-225, B. CLASSON ET AL. 'The hinge region of the CD8alpha chain: structure, antigenicity, and utility in expression of immunoglobulin superfamily domains.' see abstract see figures 1,3	1-15
A	--- WO-A-93 19163 (YEDA RESEARCH AND DEVELOPMENT COMPANY LTD.) 30 September 1993 see example 3 see claims	1,2,5-15
A	--- JOURNAL OF CELLULAR BIOCHEMISTRY, SUPPLEMENT, no. 14B, 1990 NEW YORK NY, USA, page 70 Z. ESHHAR ET AL. 'Design of cytotoxic T lymphocytes with antibody-type specificity against tumor cells using chimeric TcR.' * abstract CE112 *	1,2, 5-13,15
A	--- PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE USA, vol. 90, no. 2, 15 January 1993 WASHINGTON DC, USA, pages 720-724, Z. ESHHAR ET AL. 'Specific activation and targeting of cytotoxic lymphocytes through chimeric single chains consisting of antibody-binding domains and the gamma or zeta subunits of the immunoglobulin and T-cell receptors.' see abstract see figure 1	1,2,5-15
A	--- EP-A-0 502 812 (CIBA-GEIGY AG) 9 September 1992 cited in the application see claims	1-3
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 95/01494

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>BIO/TECHNOLOGY, vol. 10, no. 10, October 1992 NEW YORK NY, USA, pages 1128-1132, W. WELS ET AL. 'Construction, bacterial expression and characterization of a bifunctional single-chain antibody-phosphatase fusion protein targeted to the human erbB-2 receptor.' cited in the application see abstract see figure 1</p> <p style="text-align: center;">---</p>	1-3,5-15
A	<p>THE JOURNAL OF EXPERIMENTAL MEDICINE, vol. 175, no. 1, January 1992 NEW YORK NY, USA, pages 217-225, M. SHALABY ET AL. 'Development of humanized bispecific antibodies reactive with cytotoxic lymphocytes and tumor cells overexpressing the HER2 protooncogene.' see abstract</p> <p style="text-align: center;">-----</p>	8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/EP 95/01494

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 8 and 12 (both partially, as far as an in vivo method is concerned) are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 95/01494

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9210591	25-06-92	AU-B- 643109	04-11-93
		AU-A- 9172291	08-07-92
		EP-A- 0517895	16-12-92
		US-A- 5359046	25-10-94
WO-A-9319163	30-09-93	AU-B- 3924393	21-10-93
		CA-A- 2132349	30-09-93
		EP-A- 0638119	15-02-95
		JP-T- 7505282	15-06-95
EP-A-0502812	09-09-92	AU-A- 1042192	13-08-92
		CA-A- 2060544	06-08-92
		JP-A- 5192183	03-08-93